SELF-ASSESSMENT - MODULE C – LESSON 7: THERMODYNAMICS AND HUMIDITY

I. TEMPERATURE

State the boiling points and freezing points of water for each of the following scales:

	BOILING POINT	FREEZING POINT
CELSIUS	1. **100**	2. **0**
FAHRENHEIT	3. **212**	4. **32**
KELVIN	5. **373**	6. **273**

B. The temperature outside is reported as 16° F. What is the temperature in Celsius?

$$5°F = 9°C + 160$$
$$5 \times 16 = (9 \times °C) + 160$$
$$80 = (9 \times °C) + 160$$
$$80 - 160 = 9 \times °C$$
$$\frac{-80}{9} = °C = -8.9°C$$

C. List the four ways heat is transferred.

1. **CONDUCTION**
2. **CONVECTION**
3. **RADIATION**
4. **EVAPORATION**

D. Convert the following:

1. 50° C = ___ ° F

$$5°F = 9°C + 160$$
$$5 \times °F = (9 \times 50) + 160$$
$$5 \times °F = 450 + 160$$
$$5 \times °F = 610$$
$$°F = \frac{610}{5} = 122°F$$

2. -100° C = ___ ° F

$$5°F = 9°C + 160$$
$$5 \times °F = (9 \times {}^{-}100) + 160$$
$$5 \times °F = {}^{-}900 + 160$$
$$5 \times °F = {}^{-}740$$
$$°F = \frac{{}^{-}740}{5} = {}^{-}148°F$$

3. 39° C = ___ ° F

$$5°F = 9°C + 160$$
$$5 \times °F = (9 \times 39) + 160$$
$$5 \times °F = 351 + 160$$
$$5 \times °F = 511$$
$$°F = \frac{511}{5} = 102.2°F$$

4. -10° C = ___ ° F

$$5°F = 9°C + 160$$
$$5 \times °F = (9 \times {}^{-}10) + 160$$
$$5 \times °F = {}^{-}90 + 160$$
$$5 \times °F = 70$$
$$°F = \frac{70}{5} = 14°F$$

5. 212° F = ___ ° C

$$5°F = 9°C + 160$$
$$5 \times 212 = (9 \times °C) + 160$$
$$1{,}060 = (9 \times °C) + 160$$
$$1{,}060 - 160 = 9 \times °C$$
$$\frac{900}{9} = °C = 100°C$$

6. -40° F = ___ ° C

$$5°F = 9°C + 160$$
$$5 \times {}^{-}40 = (9 \times °C) + 160$$
$${}^{-}200 = (9 \times °C) + 160$$
$${}^{-}200 - 160 = 9 \times °C$$
$$\frac{{}^{-}360}{9} = °C = -40°C$$

7. 104° F = ___ ° C

$$5°F = 9°C + 160$$
$$5 \times 104 = (9 \times °C) + 160$$
$$520 = (9 \times °C) + 160$$
$$520 - 160 = 9 \times °C$$
$$\frac{360}{9} = °C = 40°C$$

8. - 20° F = ___ ° C

$$5°F = 9°C + 160$$
$$5 \times {}^{-}20 = (9 \times °C) + 160$$
$${}^{-}100 = (9 \times °C) + 160$$
$${}^{-}100 - 160 = 9 \times °C$$
$$\frac{{}^{-}260}{9} = °C = {}^{-}28.9°C$$

9. 30° C = ____ ° K

$$\begin{aligned} {}^\circ K &= {}^\circ C + 273 \\ {}^\circ K &= 30 + 273 = 303 {}^\circ K \end{aligned}$$

10. 11° C = ___ ° K

$$\begin{aligned} {}^\circ K &= {}^\circ C + 273 \\ {}^\circ K &= 11 + 273 = 284 {}^\circ K \end{aligned}$$

11. 218° K = ___ ° C

$$\begin{aligned} {}^\circ C &= {}^\circ K - 273 \\ {}^\circ C &= 218 - 273 = -55 {}^\circ C \end{aligned}$$

12. 412° K = ___ ° C

$$\begin{aligned} {}^\circ C &= {}^\circ K - 273 \\ {}^\circ C &= 412 - 273 = 139 {}^\circ C \end{aligned}$$

13. 32° F = ___ ° K

$$\begin{aligned} 5 {}^\circ F &= 9 {}^\circ C + 160 \\ 5 \times 32 &= (9 \times {}^\circ C) + 160 \\ 160 &= (9 \times {}^\circ C) + 160 \\ 160 - 160 &= 9 \times {}^\circ C \\ \frac{0}{9} &= {}^\circ C = 0 {}^\circ C \\ {}^\circ K &= {}^\circ C + 273 = 273 {}^\circ K \end{aligned}$$

14. 310° K = ___ ° F

$$\begin{aligned} {}^\circ K - 273 &= {}^\circ C \\ 310 - 273 &= {}^\circ C = 37 {}^\circ C \\ 5 {}^\circ F &= 9 {}^\circ C + 160 \\ 5 \times {}^\circ F &= (9 \times 37) + 160 \\ 5 \times {}^\circ F &= 333 + 160 \\ 5 \times {}^\circ F &= 493 \\ {}^\circ F &= \frac{493}{5} = 98.6 {}^\circ F \end{aligned}$$

II. HEAT

A. Derive the following caloric contents (in kcal) for the following:

1. A bowl of Lucky Charms that has 1 gram of fat, 27 grams of carbohydrate and 2 grams of protein.

$$\begin{aligned} &1 g \text{ of fat} \times \frac{9 \text{ kcal}}{\text{gm of fat}} = 9 \text{ kcal} \\ &27 g \text{ of CHO} \times \frac{4 \text{ kcal}}{\text{gm of CHO}} = 108 \text{ kcal} \\ &2 g \text{ of protein} \times \frac{4 \text{ kcal}}{\text{gm of protein}} = 8 \text{ kcal} \\ &\text{Total kcal} = 125 \text{ kcal or } 125{,}000 \text{ cal} \end{aligned}$$

2. Two teaspoons of peanut butter that has 16 grams of fat, 7 grams of carbohydrate and 7 grams of protein.

$$\begin{aligned}
&16g\ of\ fat \times \frac{9\ kcal}{gm\ of\ fat} = 144\ kcal \\
&7\ g\ of\ CHO \times \frac{4\ kcal}{gm\ of\ CHO} = 28\ kcal \\
&7\ g\ of\ protein \times \frac{4\ kcal}{gm\ of\ protein} = 28\ kcal \\
&Total\ kcal = 200\ kcal\ or\ 200{,}000\ cal
\end{aligned}$$

3. ½ cup of Cream of Chicken soup that has 3 grams of fat, 10 grams of carbohydrate and 3 grams of protein.

$$\begin{aligned}
&3g\ of\ fat \times \frac{9\ kcal}{gm\ of\ fat} = 27\ kcal \\
&10\ g\ of\ CHO \times \frac{4\ kcal}{gm\ of\ CHO} = 40\ kcal \\
&3\ g\ of\ protein \times \frac{4\ kcal}{gm\ of\ protein} = 12\ kcal \\
&Total\ kcal = 79\ kcal\ or\ 79{,}000\ cal
\end{aligned}$$

4. Two ounces of chopped chicken that has 1 gram of fat, 0 grams of carbohydrate and 13 grams of protein.

$$\begin{aligned}
&1g\ of\ fat \times \frac{9\ kcal}{gm\ of\ fat} = 9\ kcal \\
&0g\ of\ CHO \times \frac{4\ kcal}{gm\ of\ CHO} = 0\ kcal \\
&13\ g\ of\ protein \times \frac{4\ kcal}{gm\ of\ protein} = 52\ kcal \\
&Total\ kcal = 61\ kcal\ or\ 61{,}000\ cal
\end{aligned}$$

III. Humidity and Aerosol

A. Calculate the relative humidity (RH) if the absolute humidity (AH) today is 18.4 mg/L and the temperature is 23° C.

$$\begin{aligned}
&\%RH = \frac{Content}{Capacity} \times 100\% \\
&\%RH = \frac{18.4\ ^{mg}\!/_{L}}{20.6\ ^{mg}\!/_{L}} \times 100\% \\
&\%RH = .893 = 89.3\%
\end{aligned}$$

B. Calculate the relative humidity (RH) if the absolute humidity (AH) is 25 mg/L and the temperature is 30° C.

$$\%RH = \frac{Content}{Capacity} \times 100\%$$

$$\%RH = \frac{25 \, mg/L}{30.4 \, mg/L} \times 100\%$$

$$\%RH = .822 = 82.2\%$$

C. Calculate the relative humidity (RH) if the absolute humidity (AH) is 18.4 mg/L and the temperature is 98.6° F.

$$\%RH = \frac{Content}{Capacity} \times 100\%$$

$$\%RH = \frac{18.4 \, mg/L}{43.8 \, mg/L} \times 100\%$$

$$\%RH = .420 = 42.0\%$$

D. Calculate the relative humidity is the absolute humidity is 23.0 mg/L and the temperature is 25° C.

$$\%RH = \frac{Content}{Capacity} \times 100\%$$

$$\%RH = \frac{23.0 \, mg/L}{23.0 \, mg/L} \times 100\%$$

$$\%RH = 1.00 = 100.0\%$$

E. Calculate the relative humidity if the PH_2O today is 19.8 mm Hg and the temperature is 37° C.

A content of 19.8 mmHg occurs at temperature of 22°C.
This is equivalent to a content at this temperature is 19.4 mg/L

$$\%RH = \frac{Content}{Capacity} \times 100\%$$

$$\%RH = \frac{19.8 \, mg/L}{43.8 \, mg/L} \times 100\%$$

$$\%RH = .452 = 45.2\%$$

F. Calculate the relative humidity if the PH_2O today is 17.5 mm Hg and the temperature is 22° C.

$$\%RH = \frac{Content}{Capacity} \times 100\%$$

$$\%RH = \frac{17.5 \, mg/L}{19.4 \, mg/L} \times 100\%$$

$$\%RH = .902 = 90.2\%$$

G. Calculate the absolute humidity (AH) if the relative humidity (RH) is 50% and the temperature is 25° C.

$$AH = Capacity \times \%RH$$
$$AH = 23\, {}^{mg}\!/_{L} \times 0.50 = 11.5\, {}^{mg}\!/_{L}$$

H. If the air temperature is 20° C and the relative humidity is 30%, calculate the absolute humidity (AH).

$$AH = Capacity \times \%RH$$
$$AH = 17.3\, {}^{mg}\!/_{L} \times 0.30 = 5.19 \approx 5.2\, {}^{mg}\!/_{L}$$

I. Calculate the absolute humidity if the temperature is 34° C and the relative humidity is 45%.

$$AH = Capacity \times \%RH$$
$$AH = 37.6\, {}^{mg}\!/_{L} \times 0.45 = 16.9\, {}^{mg}\!/_{L}$$

J. Calculate the absolute humidity (AH) if the temperature is 37° C and the relative humidity (RH) is 100%.

$$AH = Capacity \times \%RH$$
$$AH = 43.8\, {}^{mg}\!/_{L} \times 1.00 = 43.8\, {}^{mg}\!/_{L}$$

K. Calculate the humidity deficit of inspired air at 30° C and a relative humidity is 65%.

$$AH = Capacity \times \%RH$$
$$AH = 30.4\, {}^{mg}\!/_{L} \times 0.65 = 19.8\, {}^{mg}\!/_{L}$$
$$HD = Absolute\ Humidity\ \text{-}\ Body\ Humidity$$
$$HD = 19.8\, {}^{mg}\!/_{L} - 43.8\, {}^{mg}\!/_{L} = -24.0\, {}^{mg}\!/_{L}$$

L. Calculate the humidity deficit of inspired air at 37° C and a relative humidity of 100%.

$$AH = Capacity \times \%RH$$
$$AH = 43.8\, {}^{mg}\!/_{L} \times 1.00 = 43.8\, {}^{mg}\!/_{L}$$
$$HD = Absolute\ Humidity\ \text{-}\ Body\ Humidity$$
$$HD = 43.8\, {}^{mg}\!/_{L} - 43.8\, {}^{mg}\!/_{L} = 0\, {}^{mg}\!/_{L}$$

M. Calculate the humidity deficit of inspired air at 20° C and a relative humidity of 80%.

$$AH = Capacity \times \%RH$$
$$AH = 17.3\, {}^{mg}\!/_{L} \times 0.80 = 13.8\, {}^{mg}\!/_{L}$$
$$HD = Absolute\ Humidity\ \text{-}\ Body\ Humidity$$
$$HD = 13.8\, {}^{mg}\!/_{L} - 43.8\, {}^{mg}\!/_{L} = 30\, {}^{mg}\!/_{L}$$

IV. CYLINDER DURATION CALCULATIONS

A. The gauge on an H cylinder of O_2 reads 2000 psig. About how long would the contents of this cylinder last, until completely empty, at a flow of 6 L/min?

$$\textit{Duration of Cylinder} = \frac{\textit{Amount of Gas}}{\textit{Flow}}$$

$$\textit{Duration of Cylinder} = \frac{\textit{Pressure (psig)} \times \textit{Cylinder Factor}}{\textit{Flow (L/min)}}$$

$$\textit{Duration of Cylinder} = \frac{2{,}000 \text{ psig} \times 3.14}{6 \, L/min} = \frac{6{,}280}{6} = 1046.7 \text{ min} = 17 \text{ hours, } 27 \text{ min.}$$

B. The gauge on an E cylinder of O_2 reads 800 psig. About how long would the contents of this cylinder last, until completely empty, at a flow of 3 L/min?

$$\textit{Duration of Cylinder} = \frac{\textit{Amount of Gas}}{\textit{Flow}}$$

$$\textit{Duration of Cylinder} = \frac{\textit{Pressure (psig)} \times \textit{Cylinder Factor}}{\textit{Flow (L/min)}}$$

$$\textit{Duration of Cylinder} = \frac{800 \text{ psig} \times 0.28}{3 \, L/min} = \frac{224}{3} = 74.7 \text{ min} = 1 \text{ hour}, 14.6 \text{ min.}$$

C. You are planning a patient transport that will take about 2 hours. The patient requires manual ventilation with 10 L/min of O_2. What is the minimum number of full E cylinders (2,000 psig) would you need to take with you?

$$\textit{Duration of Cylinder} = \frac{\textit{Amount of Gas}}{\textit{Flow}}$$

$$\textit{Duration of Cylinder} = \frac{\textit{Pressure (psig)} \times \textit{Cylinder Factor}}{\textit{Flow (L/min)}}$$

$$\textit{Duration of Cylinder} = \frac{2{,}000 \text{ psig} \times 0.28}{10 \, L/min} = \frac{560}{10} = 56 \text{ min.}$$

3 cylinders will be needed (2 would leave you 8 minutes short!)

D. One L of liquid O_2 is the equivalent of about how many L of gaseous O_2?
860 L

E. 5 pounds of liquid oxygen is present in a canister. If a nasal cannula is being used at 3 l/min, how long will the canister last?

$$\textit{Amount of Gas in Cylinder} = \frac{\textit{Liquid } O_2 \textit{ weight} \times 860}{2.5 \, lb/L}$$

$$\textit{Amount of Gas} = \frac{5 \text{ lb} \times 860}{2.5 \, lb/L} = \frac{4{,}300}{2.5} = 1{,}720 \, L$$

$$\textit{Duration of Cylinder} = \frac{\textit{Amount of Gas}}{\textit{Flow}}$$

$$\textit{Duration of Cylinder} = \frac{1{,}720 \, L}{3 \, L/min} = 573.3 \text{ min} = 9 \text{ hours, } 33 \text{ minutes!}$$

F. 35 pounds of liquid oxygen is in a stationary reservoir. If a simple mask running at 6 liters/minute is attached, how long will the reservoir last?

$$\textit{Amount of Gas in Cylinder} = \frac{\textit{Liquid } O_2 \textit{ weight} \times 860}{2.5\, lb/L}$$

$$\textit{Amount of Gas} = \frac{35\ lb \times 860}{2.5\, lb/L} = \frac{30{,}100}{2.5} = 12{,}040\ L$$

$$\textit{Duration of Cylinder} = \frac{\textit{Amount of Gas}}{\textit{Flow}}$$

$$\textit{Duration of Cylinder} = \frac{12{,}040\ L}{6\, L/min} = 2006.7\ min = 33\ \textit{hours}, 27\ \textit{minutes!}$$